Dynamometer Tests of Brake Shoes under Wet Conditions for the High Speed Trains

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***Abstract*—** This paper discuss comparative studies of the wheel tread brake with composite brake blocks between under conditions with dry and wet using the dynamometer tests for the high speed trains. Generally brake system of railway vehicles has a crucial role for the safety as well as riding quality of passengers. And brake dynamometers are widely used to evaluate the performance of brake systems and test the brake parts under various environments (weight, velocity, brake force, wet-dry conditions). Especially, in the process of the brake stops, the friction coefficients between under dry and wet conditions must not deviate from each other by more than 15% under the same testing conditions. Experiments on the brake dynamometer for the high speed trains are shown to illustrate the comparative studies of the tread brake of dynamometer tests between under dry and wet conditions with initial vehicle speed at 200 [km/h] and 80 [km/h] considering the 920 [mm] wheel diameter, respectively.

***Keywords*—** Tread Brake Blocks, Brake Dynamometer, Railway Vehicle, Friction Coefficient. Wet Condition

I. Introduction

ALL rolling stock has some form of braking device in order to decelerate and stop if necessary. During the early 19th century various attempts were made to get away from the concept of vehicle brakes which had to be individually controlled and provide a train brake with one point of control. A scheme of 1840 had a chain which ran along the train to the guard's position at the rear where it was wound round a drum. To apply the brake the drum was lowered until it touched an axle, causing it to rotate and tighten the chain. Levers connected to the chain applied the brakes In addition, as railways developed during the mid 18th century, there were a number of accidents caused by trains becoming uncoupled (a breakaway) or just failing to stop. Sometimes, breakaways ran down a grade and collided with the following train or trains became parted and the second half ran into the front half after the crew had stopped it because they had noticed the uncoupling. The traditional form of wheel tread brake consisting of a block of friction material which could be cast iron, wood or a composition material hung from a lever and being pressed against the wheel tread by air pressure in the air brake or atmospheric pressure in the case of the vacuum brake.[1]~[5]

In an air brake system, compressed air forces a piston driven brake shoe against the wheel. The brake shoes can be made from a number of different substances, including cast iron and synthetic materials. Fig. 1 shows the skeleton diagram of signal flows of an automatic air brake system. The dump valve regulates the flow of the compressed air from the auxiliary air tank to the brake cylinder. Air compressor mounted car supplies compressed air to the air brake. The brake cylinder operates the basic braking mechanism to decrease slowly and stop the train.

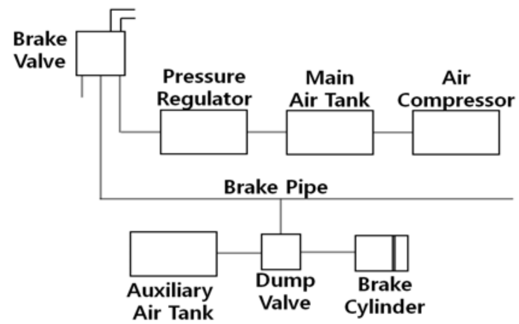


Fig. 1 skeleton diagram of an automatic air brake system

The basic braking devices used by mechanical braking systems are wheel-tread brakes, axle-mounted disc brakes, and wheel-mounted disc brakes. Fig. 2 shows the wheel-tread brake system based on a brake shoes which apply the friction to the surface of the wheel tread. The applied pressure is controlled in order to adjust the braking force. Generally high speed trains cannot use the wheel-tread rake system because it would damage the wheel tread except in emergency situations.

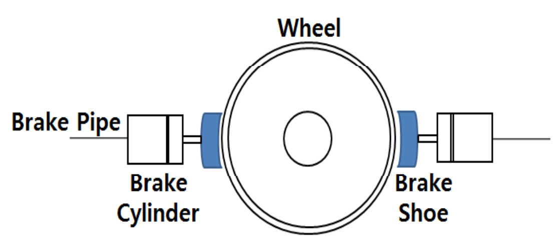
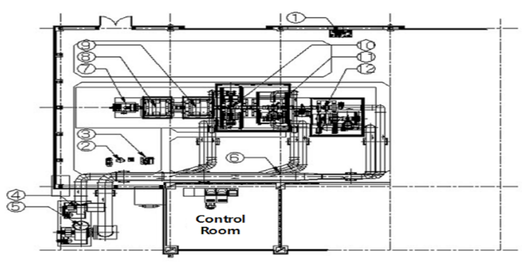


Fig. 2 wheel-tread brake system

Brake dynamometers are widely used to simulate the brake performance of the railway vehicles [6]-[9]. An example of such a dynamometer is shown in Fig. 3. There are many variations to this basic format, because of the high speed rotation operation. There is an electric motor inserting and absorbing power, an inertia section, and a test section where the brake is mounted. Each size of vehicle will require different amounts of inertia. Since these discs are in discrete steps, there is often a compromise among the number of discs and wheels, the changeable inertia. Many test procedures specify how much inertia should be used based on vehicle weight and wheel load. The test procedures performed on the brake dynamometers to cover a wide range of operational conditions. They may simulate actual vehicle operations. In passenger vehicle testing, standard procedures are often used which do not simulate typical vehicle operations, but instead, represent critical operational scenarios that test the limits of brake performance or elicit a specific type of performance characteristic.

The friction coefficients between dry and wet condition must not deviate from each other by more than 15% under the same conditions [12]. This paper contains the comparative studies of the tread brake dynamometer between dry and wet condition in initial vehicle speed at 200 [km/h] and 80 [km/h] considering the 920 [mm] wheel diameter.

This paper is organized as follows. Section 2 overviews a brake dynamometer. Section 3 describes the experiment environment for the tread brake tests. Section 4 shows the experiment results which contain the comparison of dry and wet condition when the tread brake is applied. The main conclusions are then summarized in section 5.



No.	Component	No.	Component
1	Lubrication equipment	7	DC Motor
2	Pneumatic equipment	8	Flywheel A
3	Oil pressure equipment	9	Flywheel B
4	Air supply fan	10	Tread break equipment
5	Air ventilation fan	11	Disk break equipment
6	Air duct		

Fig. 3 drawings of the brake performance dynamometer

II. Brake Dynamometer

A brake dynamometer consists of the following main elements.

◆ The drive-train parts consist of the following elements: motor, interchangeable flywheels and brake discs. The flywheels and brake disc is matched to the part number to be tested.

◆ The test bed parts consist of the following elements: caliper & adapter, power transfer axle, load bearing arm and load cell to calculate the braking force.

Fig. 4 brake performance dynamometer for high speed train

Briefly, the dynamometer used in this paper has the following features that make it suitable for brake testing:

(1) a 397 [kW] (540 [HP]) DC motor capable of speeds from 0 to 2,500[rpm] in either direction with dynamic control.

(2) flywheel discs that allow selection of inertias in 100 [kg·m²] equal increments ranging from 400 [kg·m²] to 1,600[kg·m²] with 820[mm] wheel except 1700[kg·m²].

(3) brake cylinders capable of either 60 or 120 [kN] forces with controlled force.

(4) precise measurement system for acquisition of speed, torque, temperature, and stop distance.

(5) computer control of test sequence, test parameters, and data acquisition.

Table 1 shows the main features of the brake dynamometer that make it suitable for brake testing.

Table 1 Main specification of the brake dynamometer

Max. drive power	397kW(540HP)
Max. drive torque	2,527Nm
Max. drive speed	2,500rpm(400km/h)
Max. brake torque	25,000Nm
Pressure Brake	6,000 N x 2
Flywheel Inertia	Max./Min. 1900kg·m²/400kg·m²
Diameter of the test wheel	Φ700~1120mm
Acceleration time (0~1500rpm)	2 min. 30 sec

Brake dynamometer is designed to simulate the brake characteristic of the high speed train, and has a function of record the data which can be reproduced and help to analyze and compare the experimental object, and also is used to develop and test the brake system.

The expected effects and practical schemes of the brake dynamometer are followings:

(1) Development of the brake components, shoes, disc-pads, wheel and brake system of the high-speed & conventional train

(2) Test and performance evaluations of the brake system of the high-speed & conventional trains with the international standard

(3) Performance and certification test of the brake system of the manufactured high speed train.

III. Experimental Environment

The friction coefficients between dry and wet condition must not deviate from each other by more than 15% under the same conditions according to the requirements of the UIC CODE 541-4. [12]

The instantaneous friction coefficient μ_a , which is determined in any moment of braking by the ratio of total braking force F_t to total contact force F_b , is calculated as

$$\mu_a = \frac{F_t}{F_b} \tag{1}$$

And the mean friction coefficient μ_m determined from reaching 95% of the nominal contact force F_b of the friction coefficient μ_m for the braking distance S_2 as (2).

$$\mu_m = \frac{1}{S_2}\int_0^{S_2} \mu_a \, ds \tag{2}$$

Fig. 5 shows control desk screen to control and monitor the braking performance tester.

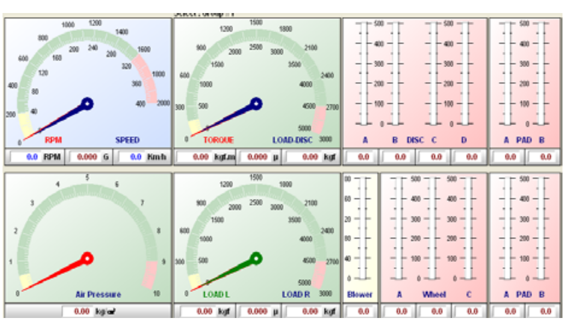


Fig. 5 control desk screen for controlling and monitoring of the braking performance tester

In the tread braking test, the initial test speed is set out at 200 [km/h] and 80 [km/h] with composite tread brake blocks for the high speed train. And the same initial speed applies for testing the brake test at dry and wet condition.

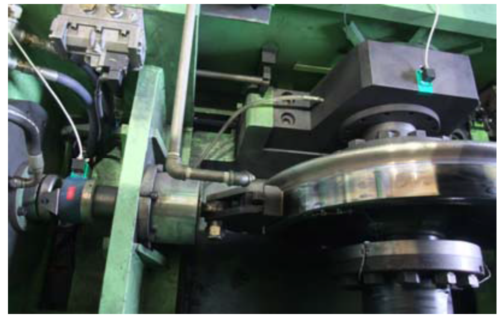
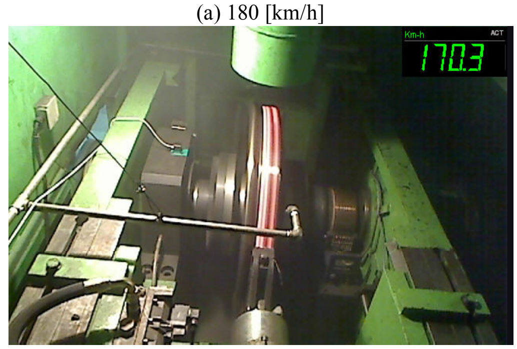


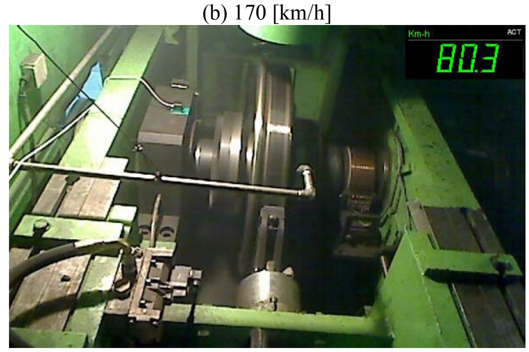
Fig. 6 tread brake blocks of the braking performance tester

Fig. 7 shows the surface of the wheel tread when it applied the braking process at initial speed of 200 [km/h]. We can observe the movement of the thermal band according to the speed variation.

(a) 180 [km/h]



(b) 170 [km/h]



(c) 80 [km/h]

Fig. 7 tread braking test at dry condition

For the tread braking test, we choose the inertia value as 800 [kg·m²] because the UIC test program prescribed 4 [ton] (mass per brake disc) in case of the high speed train. And cylinder force is accomplished under 5.9 [KN] and/or 16.6[KN], respectively.

IV. Experiments

The two step tests were performed to compare braking performance under dry condition with that of wet condition at the initial brake speed 80 [km/h] and 200 [km/h], respectively.

A. Test Results of the Tread Brake at 80 [km/h] with Brake Cylinder Force 16.69 [kN]

The experimental results including the speed curve, instantaneous friction coefficient, braking torque, and cylinder pressure from 80[km/h] to 0 [km/h] were obtained.

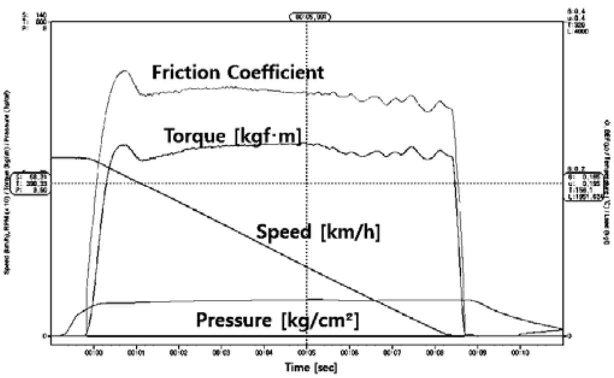


Fig. 8 measurement data under the dry condition at the initial brake speed 80 [km/h]

In the tread braking test of dry condition, braking distance was measured 55.4 [m] and braking time was gauged 6.3 [sec] during the braking test with cylinder pressure 3.34[kg/cm^2] (i.e. brake cylinder force 16.69 [kN]).

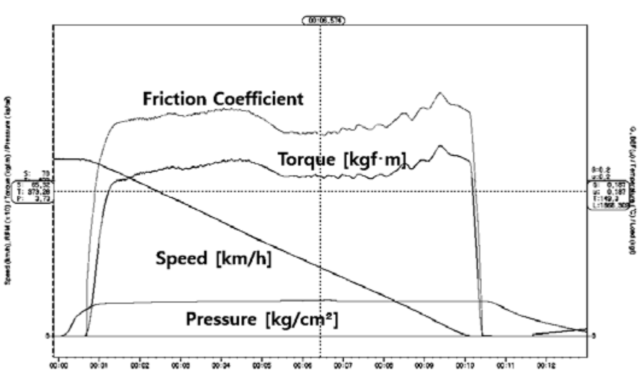


Fig. 9 measurement data under the wet condition at the initial braking speed 80 [km/h]

In the braking test of wet condition, braking distance was measured 77.7 [m] with 7.8 [sec] braking time during the braking test with the same conditions.

Tests under dry and wet condition were performed and compared the results of the braking tests at a point of view of measured braking distance, braking time, braking torque, cylinder pressure, and friction coefficient.

Fig. 10 illustrates the mutual comparisons between dry and wet conditions, which are braking distance and braking time.

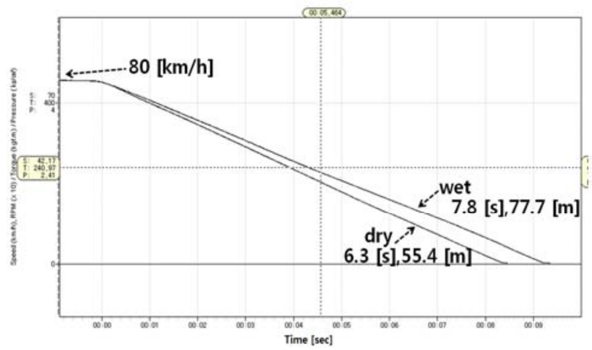


Fig. 10 mutual comparison of braking distance and braking time between dry and wet at the initial braking speed 80 [km/h]

Fig.10 indicates that the braking distance under wetting conditions has more long (about 22 [m]) because of decrement of the friction coefficient which is caused by in moisture.

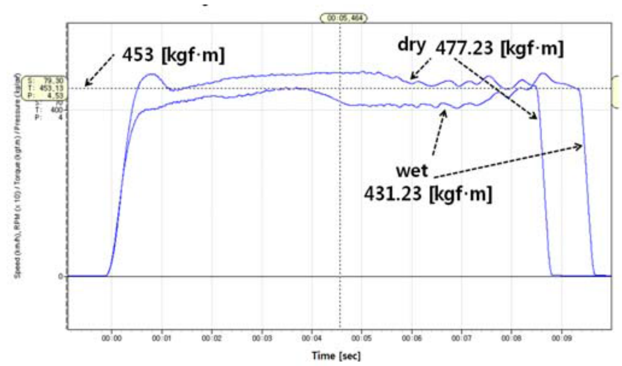


Fig. 11 mutual comparison of braking torque between dry and wet at the initial braking speed 80 [km/h]

The differences of the braking torque under dry and wet conditions appear in Fig. 11. In wet brake stops, a lower braking torque which is average values 431.23 [kgf·m] is measured comparing with braking torque (477.23 [kgf·m]) under dry brake stops.

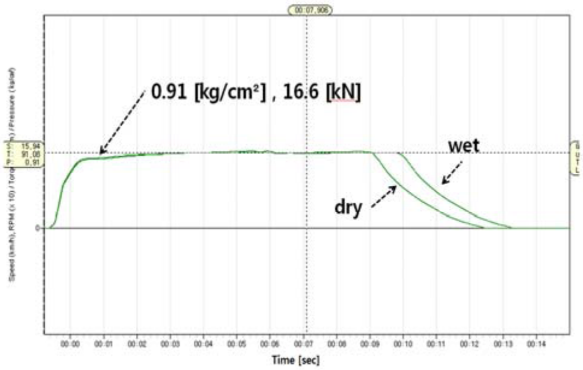


Fig. 12 mutual comparison of pressure in brake cylinder between dry and wet at the initial braking speed 80 [km/h]

Fig. 12 shows the mutual comparison of pressure in brake cylinder between dry and wet conditions. In this case the same pressure in the brake cylinder is applied continuously during the dry and wet braking operation.

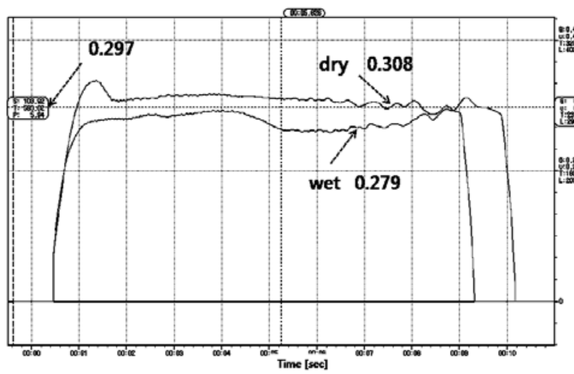


Fig. 13 mutual comparison of friction coefficient between dry and wet at the initial braking speed 80 [km/h]

Fig. 13 illuminates the instantaneous friction coefficient μ_a and the mean friction coefficient μ_m comparisons between under dry and under wet conditions. The friction coefficients between dry and wet condition must not deviate from each other by more than 15% under the same conditions. The approval deviation of the wet condition is calculated as between 0.2618 (=0.308*0.85) and 0.3542 (=0.308*1.15). The results tell us that the mean friction coefficient under wet conditions has changed within 15% against that of dry conditions. It is appropriate to verify the UIC CODE 541-4 requirements.

B. Test Results of the Tread Brake at 200 [km/h] with Brake Cylinder Force 5.9 [kN]

The experimental results including the speed curve, instantaneous friction coefficient, braking torque, and cylinder pressure from 200[km/h] to 0 [km/h] were obtained.

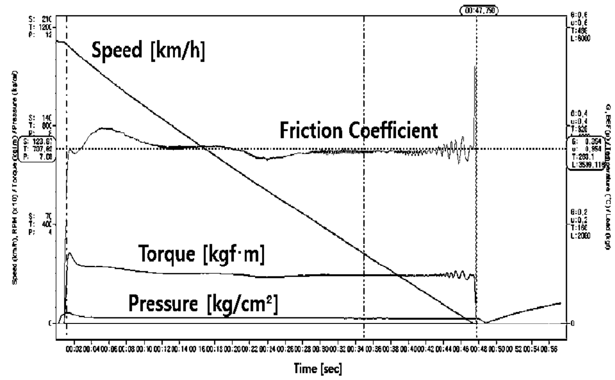


Fig. 14 measurement data under the dry condition at the initial braking speed 200 [km/h]

In the tread braking test of dry condition, braking distance was measured 1,213 [m] and braking time was gauged 45.7 [sec] during the braking test with cylinder pressure 22.6[kg/cm2] (i.e. brake cylinder force 5.9 [kN]).

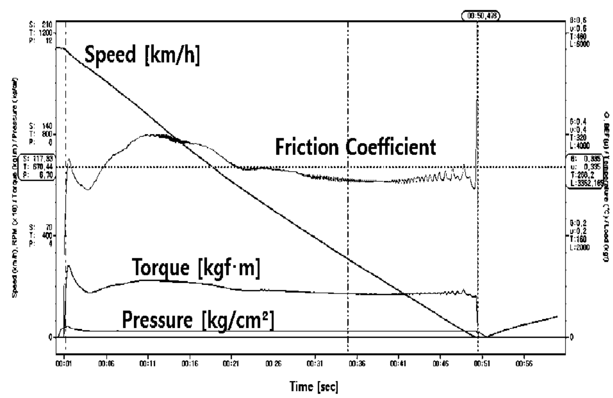


Fig. 15 measurement data under the wet condition at the initial braking speed 200 [km/h]

In the braking test of wet condition, braking distance was measured 1,263 [m] and braking time was gauged 48.4 [sec] during the braking test with the same conditions.

Two kinds of braking tests were performed and compared the results of the braking tests at a point of view of measured braking distance, braking time, braking torque, cylinder pressure, and friction coefficient.

Fig. 16 illustrates the mutual comparisons between dry and wet conditions, which are braking distance and braking time.

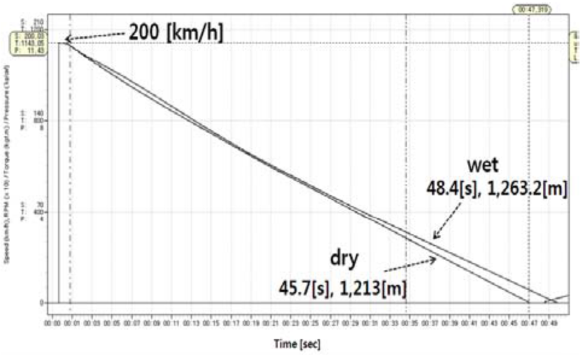


Fig. 16 mutual comparison of braking distance and braking time between dry and wet at the initial braking speed 80 [km/h]

Fig.16 indicates that the braking distance under wetting conditions has more long (50 [m]) because of decrement of the friction coefficient which is caused by in moisture.

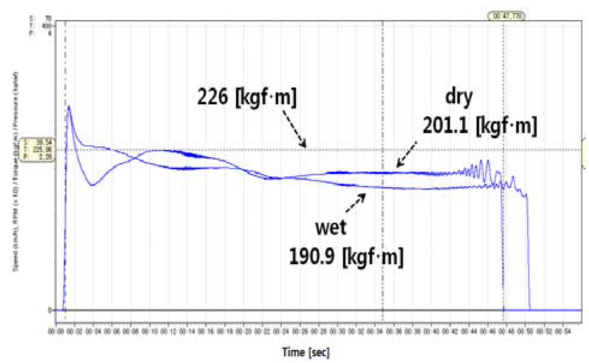


Fig. 17 mutual comparison of braking torque between dry and wet at the initial braking speed 80 [km/h]

The differences of the braking torque under dry and wet conditions appear in Fig. 17. In dry brake stops, a higher braking torque which is average values 201.10 [kgf·m] is measured comparing with braking torque (190.94 [kgf·m]) under wet brake stops.

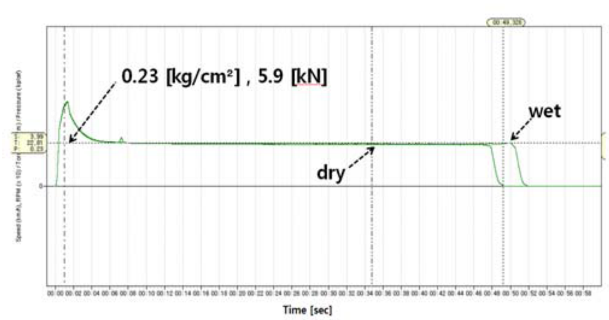


Fig. 18 mutual comparison of pressure in brake cylinder between dry and wet at the initial braking speed 80 [km/h]

Fig. 18 shows the mutual comparison of pressure in brake cylinder between dry and wet conditions. In this case the same pressure in the brake cylinder is applied continuously during the braking operation.

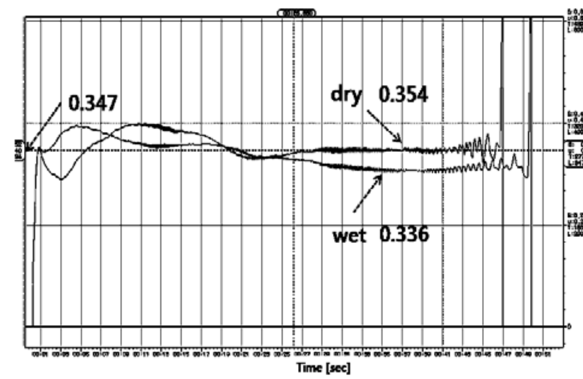


Fig. 19 mutual comparison of friction coefficient between dry and wet at the initial braking speed 80 [km/h]

Fig. 19 shows the instantaneous friction coefficient μ_a and the mean friction coefficient μ_m comparisons between under dry and under wet conditions. The results tell us that the mean friction coefficient under wet conditions has changed within 15% against that of dry conditions because the greatest and least values of the approval deviation of the wet condition are calculated as 0.4071 (= 0.354*1.15) and 0.2832 (= 0.354*0.85), respectively. It is also appropriate to verify the UIC CODE 541-4 requirements.

V. Conclusion

Brake dynamometer is designed to simulate the brake characteristic of the high speed train, and has a function of record the data which can be reproduced and help to analyze and compare the experimental object, and also is used to develop and test the brake system.

In this paper, we present a tread brake experiments on the dynamometer for high speed train in order to compare braking distance, braking time, and mean friction coefficient between dry and wet conditions in specific vehicle speed at 80 [km/h] and 200 [km/h]. In the process of the brake stops, the friction coefficients between dry and wet conditions must not deviate from each other by more than 15% under the same conditions. As a test result we could verify the mean friction coefficient under wet conditions has changed within 15% against that of dry conditions.